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γ-Al₂O₃-Supported 12-Tungstosilicic Acid as an Efficient Heterogeneous Catalyst for the Synthesis of α-Aminonitrile

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Abstract: The multicomponent Strecker reaction using trimethylsilyle cyanide was performed in very short reaction times, and α -aminonitriles were prepared in excellent yields in the presence of a catalytic amount of alumina-supported tungstosilicic acid.

Keywords: Alumina, α -aminonitrile, heterogeneous catalyst, strecker reaction, supported heteropoly acid

In the past decade, heteropoly acids (HPAs) have attracted great interest as catalysts. Their acid–base and redox properties are widely used in heterogeneous catalysis.^[1] Heteropoly compounds with Keggin structure are the most studied class of polyoxometalates because they possess relatively high thermal stability and high intrinsic acidity.^[2] HPAs have low specific area $(1-10 \text{ m}^2/\text{g})$, so it is important to increase the surface area or even better to increase the number of accessible acid sites of the HPAs. This can be achieved by dispersing the HPAs on a solid support with high surface area.^[3] Surface area enhancement, higher dispersion of acidic protons, heterogenization, and acid strength control are some of the goals of using supported HPAs. These supported catalysts are widely studied, and they have found useful applications in many organic reactions.^[4]

Bifunctional α -aminonitriles are not only versatile intermediates for

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the synthesis of α -aminoacids^[5] and various nitrogen-containing heterocycles such as imidazoles and thiadiazoles, but they also exhibit a valuable dual reactivity, which has been utilized in a broad range of synthetic applications.^[6]

They are often synthesized by the Strecker reaction^[7] and are highly useful synthons for the synthesis of biologically useful molecules such as saframycin A, a natural product with antitumor activity or phthalascidi, a synthetic analog that exhibits even greater potency.^[8] The classical procedure involves the treatment of an aldehyde or a ketone with alkaline cyanides and salts of amines, and was discovered a century and a half ago.^[7] Numerous modifications have been made to the original Strecker reaction using a variety of cvanating agents such as hydrogen cvanide, sodium or potassium cyanide, Bu₃SnCN, bis(dialkylamino)cyanobordiethylphosphorocyanidate, and trimethylsilvle anes. cvanide (TMSCN).^[9] TMSCN is a safer, more effective, and more easily handled anion source than others.^[10] The efficiency of the reaction has also been increased by the use of catalysts.^[9-11]

In continuation of our ongoing work on solid acid catalysts for developing new synthetic methodologies,^[4a,4b] herein we introduce supported HPAs as catalysts for synthesis of α -aminonitriles (Scheme 1).

Initially, the primary structures of supported HPAs were identified by comparing their Fourier transform infrared spectroscopy (FTIR) absorbtion bands to those of bulk HPAs. Keggin tungstosilicic acid (SiW) consists of an SiO₄ tetrahedron surrounded by four W_3O_{13} groups formed by edge-sharing octahedral. These groups are connected to each other by corner-sharing oxygens,^[12] and this arrangement gives rise to four types of oxygen bands between 1200 and 700 cm⁻¹, a fingerprint region for these compounds. Bulk SiW shows the characteristic IR bands at ca. 982 cm⁻¹ (terminal W=O), 928 cm⁻¹ (Si-O in central tetrahedral), and 880 and 786 cm⁻¹ (W-O-W) associated with the asymmetric vibrations in the Keggin polyanions. FTIR of the supported SiW indicates that the primary Keggin structure is preserved after supporting SiW on alumina. It should be emphasized that some bands overlapped with those of the supports.

$$\begin{array}{c} R^{1} \\ R^{2} \end{array} = 0 + R^{3}R^{4}NH \xrightarrow{HPA/Al_{2}O_{3}, r.t} \\ R^{1} \xrightarrow{C} C - NR^{3}R^{4} \\ R^{1} \xrightarrow{C} C \\ CN \end{array}$$

Scheme 1. Synthesis of α -amino nitrile.

	$H + H^{NH_2}$	R.T., Solvent	$- \bigvee_{\substack{I \\ CN}} \stackrel{H}{\underset{CN}{\overset{I}{\longrightarrow}}} \stackrel{H}{\underset{CN}{\overset{H}{\longrightarrow}}}$	
Entry	Catalyst	Solvent	Yield $(\%)^a$	Time (min)
1	PMo (2.7 mol%)	CH ₃ CN	98	3
2	PW (2.7 mol%)	CH ₃ CN	98	2
3	SiW (2.7 mol%)	CH ₃ CN	98	5
4	Al_2O_3 (1.0 g)	CH ₃ CN	80	100
5	40%PMo/Al ₂ O ₃ (0.2 g)	CH ₃ CN	98	1
6	40% PW/ Al ₂ O ₃ (0.2 g)	CH ₃ CN	94	5
7	40%SiW/Al ₂ O ₃ (0.2 g)	CH ₃ CN	98	1
8	20%SiW/Al ₂ O ₃ (0.2 g)	CH ₃ CN	92	5
9	60%SiW/Al ₂ O ₃ (0.2 g)	CH ₃ CN	98	2
10	40%SiW/Al ₂ O ₃ (0.1 g)	CH ₃ CN	94	5
11	40%SiW/Al ₂ O ₃ (0.4 g)	CH ₃ CN	98	1
12	40%SiW/Al ₂ O ₃ (0.2 g)	CH_2Cl_2	76	30
13	40%SiW/Al ₂ O ₃ (0.2 g)	C_6H_6	43	15
14	40%SiW/Al ₂ O ₃ (0.2 g)	THF	67	15

 Table 1. Effect of different catalysts under different reaction conditions for condensation of benzaldehyde, aniline, and TMSCN

^aIsolated yield.

Although the three-component Strecker reaction involving benzaldehyde, aniline, and TMSCN in the presence of catalytic amounts of the different HPAs shows excellent yield (Table 1, entries 1–3), it is a homogeneous reaction and recovery of catalyst is tedious. Thus, optimization experiments for the model reaction in the presence of a catalytic amount of HPA/ γ -Al₂O₃ were carried out. After some experimentation with respect to the different HPAs, molar ratios, and catalyst loadings, the best results were obtained in the presence of 40 wt% of SiW/ γ -Al₂O₃ with 2.5 mol% catalyst loading (Table 1, entries 4–11). It seems that acetonitrile is a much better solvent than all other tested solvents (such as dichloromethane, tetrahydrofuran, and toluene) (Table 1, entries 7, 12–14). It is striking to note that no improvements in the reaction rates and yields were observed by increasing the temperature to 90 °C.

The reaction was applied to other aliphatic, heterocyclic, and aromatic aldehydes carrying either electron-donating or electron-withdrawing substitutions and aromatic, benzylic, and aliphatic (both primary and secondary) amines (Table 2). To our knowledge, only a few reports of Strecker reactions with ketones were found in the literature,^[10–12] but as evidenced in Table 2, entries 16–19, ketones gave excellent yields at longer reaction times in this report.

R²

Т

	\rightarrow O + R ³ R ⁴ NH -	$\longrightarrow R^1 - C - NR^3R^4$				
	\mathbf{R}^{2}	TMSCN, CH ₃ CN, r.t CN				
Entry	Aldehyde/ketone	Amine	Time (min)	Yield $(\%)^a$	Ref. ^b	
1	Benzaldehyde	Aniline	1	98	10g	
2	Benzaldehyde	Benzylamine	1	98	10d	
3	Benzaldehyde	Butylamine	8	95	10g	
4	Benzaldehyde	Isobutylamine	8	94	9a	
5	3-Methoxybenzaldehyde	Aniline	2	98	9a	
6	3-Methoxybenzaldehyde	Benzylamine	8	98	9a	
7	3-Methoxybenzaldehyde	Butylamine	5	98	9a	
8	4-Chlorobenzaldehyde	Aniline	8	92	10g	
9	4-Methylbenzaldehyde	Aniline	6	96	10g	
10	Furfural	Aniline	2	98	10a	
11	Furfural	Benzylamine	3	94	10g	
12	Cinamaldehyde	Aniline	6	94	10g	
13	Thiophene-2- carboxaldehyde	Benzylamine	10	91	10d	
14	Decanal	Aniline	1	98	10d	
15	Benzaldehyde	Morpholine	2	94	9a	
16	Cyclohexanone	Benzylamine	30	90	9a	
17	Cyclohexanone	Butylamine	45	92	9a	
18	3-Methyl cyclohexanone	Benzylamine	30	95	9a	
19	3-Methyl cyclohexanone	Morpholine	30	89	9a	

Table 2. Alumina-supported $H_4SiW_{12}O_{40}$ -catalyzed synthesis of α -aminonitriles

40 wt.% Siw/Al₂O₃

^aIsolated yield

^bProducts were characterized by comparison of their spectroscopic data with those reported in the literature.

Acid-sensitive aldehydes such as furfural and cinnamaldehyde worked well without the formation of any side products (Table 2, entries 10–12). Furthermore, the reaction conditions are mild enough to perform in the presence of enolizable aldehydes such as decanal (Table 2, entry 14). These three-component coupling reactions proceeded efficiently at ambient temperature with high selectivity.

In addition, SiW/Al_2O_3 could be recovered and subsequently reused several times simply by filtering the catalyst, washing with acetonitrile, and drying in an oven at 120°C for 2 h, to remove the adsorbed reactants or product. It showed a slightly loss of activity after four successive runs: the yield of the product for the model reaction was 85% after the fourth run. Also, the reaction mixture was filtered 30 s after the first run. Then the reaction was resumed with the filtrate, in the absence of

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Strecker Reaction in the Presence of Alumina-Supported HPA

any externally added catalyst. No increase in conversion was observed after 10 min, which proves it is a real heterogenic catalyst.

In conclusion, the results presented in this article demonstrate that alumina can be regarded as a good support for HPAs. SiW/Al₂O₃ is an efficient, environmentally friendly, cheap, and nontoxic catalyst with very easy workup. Also, the present procedure represents a clean, practical, simple, mild, and time-saving method for synthesis of α -aminonitriles in short reaction times and excellent yields with 100% selectivity.

EXPERIMENTAL

Catalyst based on HPA supported on γ -Al₂O₃ was prepared by the impregnation method. The solution of HPA was prepared by dissolving an appropriate amount of HPA (with concentrations depending upon the loading required to support 20, 40, and 60 wt% HPA to alumina) in 25 mL of aqueous solution. Then 5.0 g of γ -Al₂O₃ was dropped into this solution under vigorous stirring, and the resulting solution was impregnated for 24 h. After that, catalyst was dried at room temperature for 24 h and calcined at 200°C for 3 h.

Typical Procedure for the Synthesis of *α*-Aminonitriles

A mixture of aldehyde (1 mmol), amine (1.1 mmol), TMSCN (1.5 mmol), and SiW/Al₂O₃(2.7 mol%) in acetonitrile (3 mL) was stirred at room temperature for an appropriate time (Table 2). After completion of the reaction, as indicated by thin-layer chromatography (TLC), the reaction mixture was filtered and washed with acetonitrile (2×10 mL). The combined organic layers were dried over anhydrous Na₂SO₄, concentrated in vacuo, and purified by column chromatography on silica gel (ethyl acetate/n-hexane, 1:9) to afford pure α -aminonitrile. All products were identified by comparison of their spectral data with those of the authentic samples.^[9a,10a,10d,10g]

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REFERENCES

1. (a) Holderich, W. F. In *Comprehensive Supramolecular Chemistry*; J. L. Atwood, J. E. P. Davies, D. D. MacNicol, F. Vögtle, (Eds.); Pergamon Press:

Oxford, 1996. vol. 7, p. 671; (b) Pope, M. T.; In *Comprehensive Coordination Chemistry II*; A. G. Wedd (Ed.); Elsevier: Oxford, U.K., 2004; vol. 4, p. 635;
(c) Hill, C. L. In *Comprehensive Coordination Chemistry II*; A. G. Wedd (Ed.); Elsevier: Oxford, U.K., 2004; vol. 4, p. 679.

- (a) Drago, R. S.; Dias, J. A.; Maier, T. O. An acidity scale for Brønsted acids including H₃PW₁₂O₄₀. *J. Am. Chem. Soc.* **1997**, *119*, 7702–7710; (b) Dias, J. A.; Dias, S. C. L.; Kob, N. E. Dehydration of 1-propanol using H₃PW₁₂O₄₀ as catalyst. *J. Chem. Soc., Dalton Trans.* **2001**, *3*, 228–231.
- (a) Kozhevnikov, I. V.; Sinnema, A.; Jansen, R. J. J.; Pamin, K.; Van Bekkum, H. New acid catalyst comprising heteropoly acid on a mesoporous molecular sieve MCM-41. *Catal. Lett.* **1995**, *30*, 241–252; (b) Moffat, J. B. *Metal–Oxygen Cluster—The Surface and Catalytic Properties of Heteropoly Oxometalates*; Kluwer: New York, 2001; p. 25; (c) Kozhevnikov, I. V.; Kloetstra, K. R.; Sinnema, A.; Zandbergen, H. W.; van Bekkum, H. The study of catalysts comprising heteropoly acid H₃PW₁₂O₄₀ supported on MCM-41 molecular sieve and amorphous silica. *J. Mol. Catal. A: Chem.* **1996**, *114*, 287–298.
- 4. (a) Rafiee, E.; Shahbazi, F. One-pot synthesis of dihydropyrimidones using silica-supported heteropoly acid as an efficient and reusable catalyst: Improved protocol conditions for the Biginelli reaction. J. Mol. Catal. A: Chem. 2006, 250, 57–61; (b) Rafiee, E.; Rashidzadeh, S.; Azad, A. Silica-supported heteropoly acids: Highly efficient catalysts for synthesis of α-aminonitriles, using trimethylsilyl cyanide or potassium cyanide. J. Mol. Catal. A: Catal. A: Chem. 2006, 261, 49–52; (c) Izumi, Y.; Hisano, K.; Hida, T. Acid catalysis of silica-included heteropolyacid in polar reaction media. Appl. Catal. A 1999, 181, 277–282.
- (a) Enders, D.; Shilvock, J. P. Some recent application of α-aminonitrile chemistry. *Chem. Soc. Rev.* 2000, 29, 359–373; (b) Shafran, Y. M.; Bakulev, V. A.; Mokrushin, V. S. Synthesis and properties of α-aminonitriles. *Russ. Chem. Rev.* 1989, 58, 148–162; (c) March, J. *Advanced Organic Chemistry*, 4th ed.; Wiley: New York, 1999; p. 965; (d) González-Vera, J. A.; García-López, M. T.; Herranz, R. Molecular diversity via amino acid derived α-aminonitriles: Synthesis of spirocyclic 2,6-dioxopiperazine derivatives. J. Org. Chem. 2005, 70, 3660–3666; (e) Dyker, G. Amino acid derivatives by multicomponent reactions. Angew. Chem., Int. Ed. 1997, 36, 1700–1702.
- (a) Weinstock, L. M.; Davis, P.; Handelsman, B.; Tull, R. A. General synthetic system for 1,2,5-thiadiazoles. *J. Org. Chem.* 1967, *32*, 2823–2829; (b) Matier, W. L.; Owens, D. A.; Comer, W. T.; Deitchman, D.; Ferguson, H. C.; Seidehamel, R. J.; Young, J. R. Antihypertensive Agents: Synthesis and biological properties of 2-amino-4-aryl-2-imidazolines. *J. Med. Chem.* 1973, *16*, 901–908.
- Strecker, A. Ueber die K
 ünstliche Bildung der Milchs
 äure und einen neuen, dem Glycocoll homologen K
 örper. Ann. Chem. Pharm. 1850, 75, 27–45.
- (a) Duthaler, R. O. Recent developments in the stereoselective synthesis of α-aminoacids. *Tetrahedron* 1994, *50*, 1539–1650; (b) Martinez, E. J.; Corey, E. J. Enantioselective synthesis of saframycin A and evaluation of antitumor activity relative to ecteinascidin/saframycin hybrids. *Org. Lett.* 1999, *1*, 75–78.

- 9. (a) Ranu, B. C.; Dey, S. S.; Hajra, A. Indium trichloride catalyzed one-pot synthesis of α -aminonitriles by a three-component condensation of carbonyl compounds, amines, and potassium cyanide. Tetrahedron 2002, 58, 2529-2532; (b) Harusawa, S.; Hamada, Y.; Shioiri, T. Diethyl phosphorocyanidate (DEPC), a novel reagent for the classical Strecker's α -aminonitriles synthesis. Tetrahedron Lett. 1979, 48, 4663-4666; (c) Royer, L.; De, S. K.; Gibbs, R. A. Iddine as a novel efficient reagent for the synthesis of α -aminonitriles by a three-component condensation of carbonyl compounds, amines, and trimethylsilyl cyanide. Tetrahedron Lett. 2005, 46, 4595-4597; (d) Suginome, M.; Yamamoto, A.; Ito, Y. Bis(dialkylamino)cyanoboranse: Highly efficient reagents for the Strecker-type aminative cyanation of aldehydes and ketones. Commun. 2002, 1392-1393; (e) Kobayashi, S.; Busujima, T.; Chem. Nagayama, S. Scandium triflate-catalyzed Strecker-type reactions of aldehydes, amines, and tributyltin cyanide in both organic and aqueous solutions: Achievement of complete recovery of the tin compounds toward environmentally friendly chemical processes. Chem. Commun. 1998, 981-982.
- 10. (a) Yadav, J. S.; Reddy, B. V. S.; Eeshwaraiah, B.; Srinivas, M. Montmorillonite KSF clay catalyzed one-pot synthesis of α -aminonitriles. Tetrahedron 2004, 60, 1767-1771; (b) Fetterly, B. M.; Jana, N. K.; Verkade, J. G. [HP(HNCH₂)₃N]NO₃: An efficient homogeneous and solid-supported promoter for aza and thia-Michael reactions and for Strecker reactions. Tetrahedron 2005, 61, 1-18; (c) Kobayashi, S.; Nagayama, S.; Busujima, T. Polymer scandiumcatalyzed three-component reactions leading to diverse amino ketone, amino ester, and amino nitrile derivatives. Tetrahedron Lett. 1996, 37, 9221; (d) Yadav, J. S.; Reddy, B. V. S.; Eshwaraiah, B.; Srinivas, M.; Vishnumurthy, P. Threecomponent coupling reactions in ionic liquids: A facile synthesis of α -aminonitriles. New J. Chem. 2003, 27, 462-465; (e) De, S. K.; Gibbs, R. A. Bismuth trichloride-catalyzed synthesis of α -aminonitriles. Tetrahedron Lett. 2004, 45, 7407-7408; (f) Heydari, A.; Fatemi, P.; Alizadeh, A. Lithium perchlorate/diethylether-catalyzed aminocyanation of aldehydes. Tetrahedron Lett. 1998, 39, 3049-3050; (g) De, S. K. Nickel(II) chloride-catalyzed one-pot synthesis of a-aminonitriles. J. Mol. Catal. A: Chem. 2005, 225, 169-171.
- (a) De, S. K. RuCl₃-catalyzed one-pot synthesis of α-aminonitriles. Synth. Commun. 2005, 35, 653–656; (b) De, S. K.; Gibbs, R. A. Praseodynium trifluromethylsulfonate as an efficient and recyclable catalyst for the synthesis of α-aminonitriles. Synth. Commun. 2005, 35, 961–966; (c) Kobayashi, S.; Ishitani, H.; Ueno, M. Facile synthesis of α-aminonitriles using lanthanide triflate as a Lewis acid catalyst. Synlett 1997, 115–116.
- Kozhevnikov, I. V. Catalysis for Fine Chemical Syntheses—Catalysis by Polyoxometalates; John Wiley & Sons: Chichester, 2002; p. 50.